DTMF REMOTE CONTROL
for Beacons and Repeaters

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THE UNIT described here is intended for the remote control of beacons and repeaters where a permanent telephone line is available for secure control. The unit may be used with a duplex radio link, for example when controlling a repeater, but for simplex (transmit/receive) operation, hardware and software changes will be required. Furthermore, issues such as security of control codes may inhibit its use over a public radio channel.

On ringing the telephone number of the line to which the Controller is connected, it will automatically answer after approximately two rings. A Personal Identity Number (PIN) is then entered, followed by a command using DTMF tones generated by the calling telephone to control the remote circuits and read their status.

CONTROL PROTOCOL

TWO LEVELS of control are allowed. One PIN, intended for issuing to persons *not* holding an amateur radio licence, will turn *off* all controlled circuits with no ability to switch them back *on* again using this number. This will be referred to as PIN1, and the associated all-off command referred to as a *Priority Command*. A second PIN gives access to individual *on/off* control of the remote circuits and allows the status of these, and of the Controller itself, to be read back using CW messages. This is referred to as the *User PIN*. If a Priority Command has been issued, this is indicated in the status message. Remote power supply monitoring is also featured, as the Controller maintains a backup battery to store the state of the controlled circuits during power failures. If the beacon or repeater goes off air this message allows the operator to see if power failure or a command or equipment failure is the cause. The internal battery should be able to power the PIC and DTMF decoder for one to two days. A full command listing is given later.

DESIGN

THE CIRCUIT diagram of the Controller is shown in **Fig 1**, but without details of interfacing to the telephone line. Components within the box labelled 'Line Interface' are for illustration only. A dedicated MV8870 DTMF decoder IC performs all the audio filtering, validation and data decoding and outputs a four-bit code for the DTMF digit received, plus a strobe, to a PIC microcontroller. At all times the PIC is monitoring for valid DTMF codes, whether the interface is off-line or on-line. This allows for local on-hook signalling (see later) as well as non-phone-line, or leased-line use. The decoder chip requires a 3.58MHz clock generated by a crystal; the same oscillator is also used to supply the PIC clock. The PINs are stored in the PIC's non-volatile memory and every DTMF sequence received is checked for a valid PIN. Up to three circuits can be controlled from this design and, as shown, two command outputs are in the form of a switch closure to ground intended for operating relays or similar, and one is an uncommitted 0 - 5V logic level output. Do not forget additional back-EMF protection diodes across any relay coils!

IMPORTANT NOTE

Direct connection to a telephone line requires that equipment be approved for such connection, so no complete details can be given here for such an interface. However, a suitable interface module for connection that may meet type-approval regulations is given at the end of the article. Some alternative means for making a safe connection to the Public Switched Telephone Network are also suggested. In all cases the relevant approvals and specifications should be read and followed in construction.

The PIC generates the audio CW messages used for acknowledging data entry and status messages. An LED is included to show locally when audio responses are being generated. The LED is really there only as an aid during software development and is fully software-programmable.

The final task of the PIC is to respond to the telephone line and perform the auto-answer function. An opto-isolator in the line interface monitors the line for ringing voltage and, when this is present, C8 is charged. When the switching threshold on the PIC's A4 Schmitt trigger input is reached, A3 is activated which operates the relay or switch in the line interface via TR1, seizing the line. C8 is then discharged, ready for the next call. To ensure fail-safe operation, the PIC software maintains a continuous time-driven interrupt counter. When a particular value of count is reached (after 20 seconds) the Controller will release the phone line irrespective of the state of any command entry. Every time a DTMF digit is received, the counter is reset to zero, restarting the 20-second time delay. This means that is impossible to lock up the Controller in a state that keeps the phone line latched on; to terminate a control session, just hanging up or entering no tones for 20s is all that is needed. Immediately before going off-line, a tone is sent.

A full software listing is available in the file *DTMFREM1.ASM*, available from the sources given later.

The nominally-5V power supply for the MV8870 and the PIC is generated by a NiMH battery which is float-charged by a constant-current source of 10mA. With a PIC current consumption of 6mA, this leaves 4mA to keep the battery topped up. The voltage input can be anything from 7 to 20V.

CONSTRUCTION AND SET-UP

A SURFACE-MOUNT, single-sided PCB layout is given in **Fig 2(a)** and the component layout in **Fig 2(b)**. Alternatively, if SMT construction is not desired, constructors can make their own through-hole version or even use Veroboard or similar. Two wire links are needed on the PCB - one carries the clock signal from the MV8770 to the PIC, the other carries the power-monitoring signal from TR5. Observant readers may notice that the data lines from the DTMF receiver to the Controller are crossed over, Q1 to B4, Q2 to B3 etc. This was done solely to make PCB layout easier without resorting to wire links; the correction to the data is made in the PIC software.

Firstly, the charging current needs to be set up. Power up the whole circuit without any line interface or external relays supplied from the 5V supply, and measure the current into the battery. By selecting the value(s) for the parallel combination R13-R14, ensure the current into the battery is in the range 4 to 6mA. A typical value will be in the region of 60Ω total. The PIC and MV8870 will consume about 6mA between them, meaning the current source has to regulate to around 10 to 12mA. Note that, when measuring the input current to the Controller, this figure will be increased by that needed for the power indicator LED.

Programmed PICs using the *DTMFREM1* software are configured at switch-on with circuits 1 and 2 on, and circuit 3 off. Customised software will allow this to be changed. After switching on, check that the command outputs are in the correct state - this should prove that the Controller is working. Then, while monitoring the audio output with headphones or an audio amplifier, short the Ring Input (RI) to 5V. After about 1s, the auto-answer tone will be heard and the line-control output will be activated. Remove the short and, after approximately 20s, another tone will be heard and the line-control will be released.

The PCB layout allows for Commands 1 and 2, as well as the line-control, to be performed by

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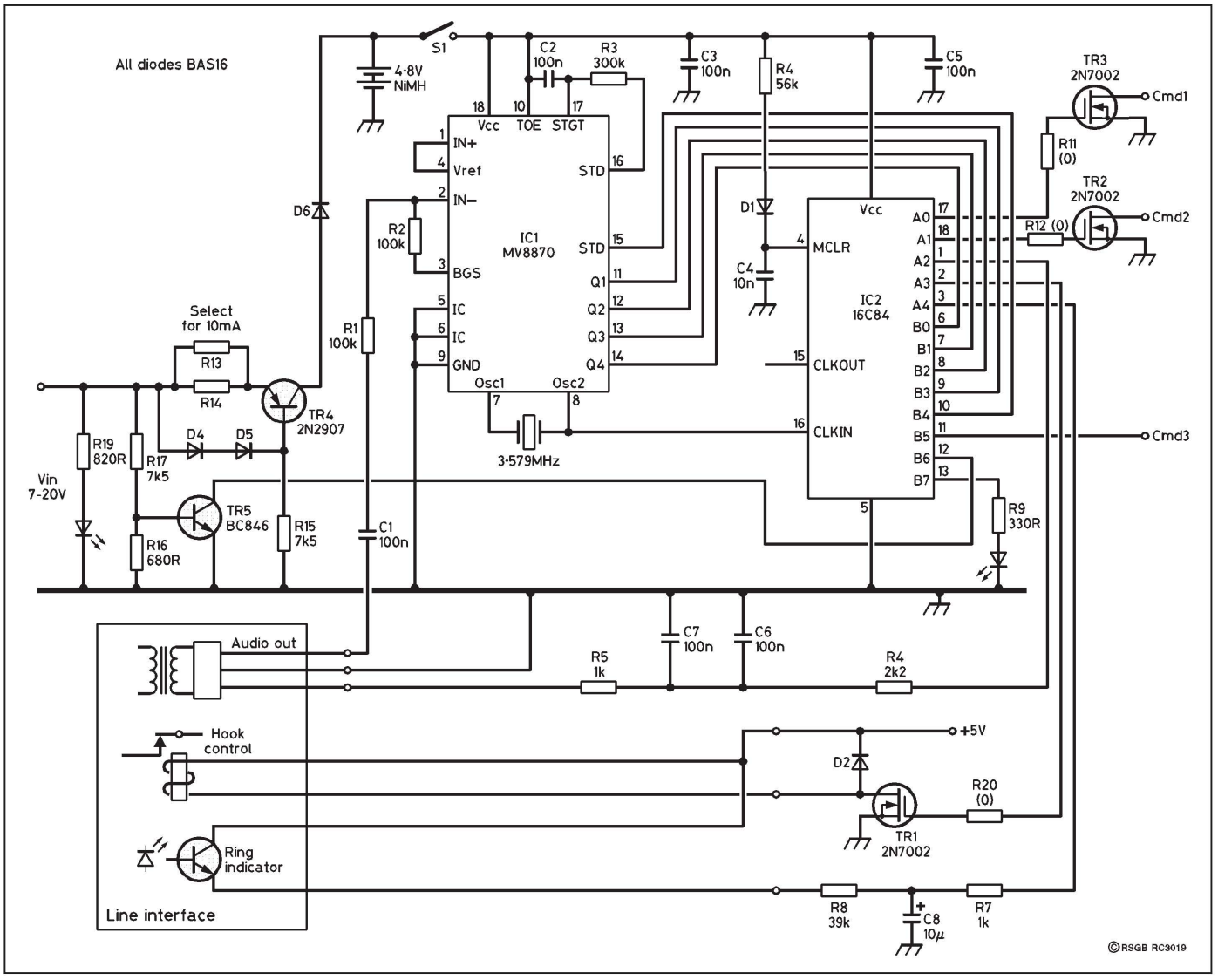

Fig 1: Complete circuit diagram of the DTMF Remote Controller.

relays with the driver transistors placed on the PCB. A spike-catching diode is provided for the line-control relay when used with the 5V supply. If using a line-control relay with a separate supply, this diode should be removed and replaced by one returned to the external supply. The replacement of the zero-ohm links with suitable current-limiting resistors on the gate drive of the drive transistors permits their replacement with bipolar transistors, perhaps of higher voltage or current rating. A 0-5V output can also be taken, and in the case of non-relay-switched control (see below), a resistor can be added here suitable for driving opto-isolators such as in a line-interface module

For complete testing, some means of feeding DTMF audio tones at a voltage level of greater than 0.1V RMS to the audio input is needed. If a phone line interface is in use, this can conveniently be done by connecting another phone in parallel to generate the tones (see note 1). Otherwise, an audio amplifier and microphone can be pressed into service, using a telephone or, preferably, a DTMF keypad to generate the codes.

The PIC is mounted in an IC socket, meaning that software updates and changes can easily be made by reprogramming. The use of a removable PIC also means operation can be customised to individual users' needs, as these may change.

TELEPHONE LINE INTERFACING

TELEPHONE OPERATORS are very concerned that connections to their network should not cause any harm to exchange signalling equipment, personnel or correct operation of the network. As part of European and world harmonisation, the requirement for individual approval of all such equipment is no longer needed (BABT approval), but design specifications and rules are in place which must be adhered to if direct connections are contemplated and approval by random selection of production items is considered satisfactory. Most of these are concerned with safety isolation, voltage breakdown and testing, but also such matters as audio drive levels and out-of-frequency-band energy are specified (see note 1).

Fortunately, ready-made modules are now available to perform all the line interfacing and safety barrier functions. Using one of these means that, when coupled with correct construction techniques and housing, a design can be made that is capable of meeting the regulations. No details will be given here as it is each builder's own responsibility to ensure his own construction meets the requirements. One suitable module, the ETAL P3400, is available from Farnell, part number 761-000. Farnell can supply a data sheet on request, to which reference should be made. Etal also supplies a wide range of ready-made components for making up line-interfacing circuitry meeting the approvals. See their web page (2) for details of suitable components.

The design here will directly interface to this module with one minor change. TR1 and D2 are no longer needed to drive the On-Hook control input, as this is controlled by an internal opto-isolator rather than the more traditional relay. Instead, connection is made directly to A3 on the PIC adding a suitable current-limiting resistor at the R20 position. The audio input and output lines, and Ring Detect input, will interface directly to the respective module points. For all other interfacing and setting-up details, the data sheet should be consulted.

Other designs are suitable; various modems have been published in different electronics magazines over the years and many of the line-interfaces in these are approved designs, although obviously they all suffered from the same approval problems of home-constructed equip-

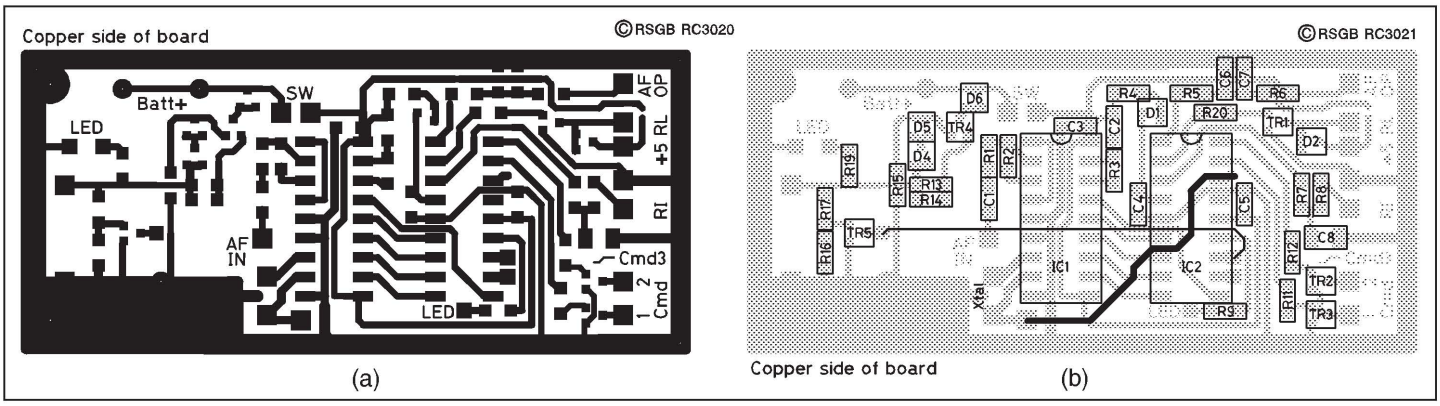

Fig 2: (a) The PCB track layout of the DTMF Remote Controller; (b) The component placements. Both are shown actual size.

ment. Another route might be to cannibalise an old modem (carefully) - ancient low-speed units (and even 28,800b/s ones) are frequently thrown away, as are fax machines. All will have suitable approved interfacing which, with care, could be pressed into service by carefully separating the line interface and removing the modem components (see note 2).

Many of the data sheets and application notes for telephone-line-interfacing components give helpful information on design and construction techniques - one of the most important, it appears, is the need for at least 5mm creep distance over a PCB surface, between any connection to the PSTN network and connections to the user's side.

COMPONENT AVAILABILITY

SOFTWARE FOR THE PIC is available either from myself (3, 4) or from the RSGB web site (5). Ready-programmed PICs are available for £8 each, inclusive of post and packing. Please state your required PINs when ordering, so these can be programmed into the PIC. Some custom changes to software and command protocol may also be possible - you only have to ask!

Small quantities of surface-mount PCBs can be supplied on request. Price on application.

All components for the Controller module are readily available from suppliers such as Farnell.

UPDATES PLANNED

SOFTWARE UPDATES will occur from time to time. One change underway while this article is being prepared is the inclusion of multiple Priority Command PINs, one for turning off each circuit instead of all together. Status messages available via the user PIN will be changed to reflect this. Another will be a command counter, to assist in monitoring commands issued by multiple users. The software name will be changed to reflect updates; look for files with the generic name DTMFREMx where x is a digit reflecting the upgrade number.

Another version planned will be a controller for use with simplex radio links. Here, apart from Tx/Rx control, a squelch input from the receiver will be needed for the Controller to be able to know when to send back acknowledgements and status messages. The same circuit and PCB layout will be adopted, with RI being replaced by Squelch and Hook Control by Transmit / Receive switching. A higher-security level of PIN entry will be needed to prevent hackers from intercepting the codes transmitted over the air and this will probably make use of a rolling code sequence where the PIN will change each time a command is sent. This is the same way that security for most wireless car entry and immobiliser systems is maintained.

NOTES

(1) If testing by using another telephone in parallel and on an exchange circuit, do not choose a PIN which, when followed by any other PIN or commands, could generate a valid phone number, otherwise calls may be inadvertently made to unsuspecting subscribers! Starting the sequence the first time with a known invalid digit will be effective. For most of the time during testing, the exchange will be sending an annoying recorded voice saying the number is invalid, or giving a 'number unobtainable' tone, but this can safely be ignored.

(2) I developed my own lower-cost line interface with discrete components, based around one used for a modem published in *Wireless World* about 15 years ago. For the more adventurous and daring constructors, I can supply this circuit on an individual basis, *on the understanding that it is your responsibility to ensure that it meets safety and construction requirements.* ♦

www.

(1) **BABT approval** — **www.babt.co.uk**
(2) **Line interface components** — **www.etal.ltd.uk**

PIC SOFTWARE

(3) **actalbot@dera.gov.uk**
(4) **g4jnt@thersgb.net**
(5) **www.rsgb.org**

OPERATING INSTRUCTIONS

Version 1 - Instructions applicable to PIC code *DTMFREM1* only

THIS REMOTE CONTROL unit will auto-answer a telephone line and command three circuits on or off depending on DTMF codes sent to it. CW responses are generated showing the status of the controlled circuits.

Two separate PINs are needed to access the Controller:

PIN 1 issues a global turn-off and is intended to allow non-licence holders to turn off beacon or repeater equipment, without having the ability to switch it back on again. Receipt of PIN1 sets a status flag that can be read by the user.

PIN 2 gives access to a command set which controls individual *on/off* for each command circuit and allows the Controller's status to be read back in the form of a CW message.

OPERATION

AFTER DIALLING the Controller's telephone number, it will answer after approximately two rings, and reply with a 1800Hz tone. At the end of this tone one of the two PINs may be entered:

Entering PIN1 will turn off all controlled circuits and respond with a double bleep (a slow 'I' or 'TT' in Morse) to show the command has executed. If this is not heard, repeat by entering the full PIN1 again.

Enter PIN2 and, after a short delay, the Controller will respond with a blip to indicate that it is now waiting for a single command digit. If no blip is heard, re-enter PIN2. After hearing the response, enter a command from the list that follows. Depending on the command entered, the Controller will respond with either a 'K' in Morse, or the status messages followed by a 'K'. Acknowledgement is sent even if invalid command digits are entered; invalid entries will be ignored.

The command sequence can be repeated continuously, with PIN1 + Command or PIN2 + Command entered each time. At any stage, if no response appears from a PIN or command entered, just repeat until accepted. Problems can occur if tones are entered too quickly and before an acknowledgement for a previous entry is sent. On completion of the commands, it is advisable to check the status with command '7' before closing the link.

The single digit commands are:

1	Turns ON Circuit 1
2	Turns ON Circuit 2
3	Turns ON Circuit 3
4	Turns OFF Circuit 1
5	Turns OFF Circuit 2
6	Turns OFF Circuit 3
7	Replays the Status of the Controller; see below for status messages.
8	Resets the Status flags; at the moment only P is implemented.
9 # *	Not used.

Status Messages:

'P'	Returned in CW if a Priority turn-off command , PIN1, has been issued. Cleared with the '8' command.
'1'	Circuit 1 is ON
'2'	Circuit 2 is ON
'3'	Circuit 3 is ON
'B'	Main power supply at the remote site is off (the Controller includes its own local battery to maintain status and auto-answer).

There is a built-in delay between hearing a PIN or Command and its response, to allow use with one-piece telephones, but units that mute the audio when sending tones may give problems if the un-mute delay is too long.

The Controller will send a 1800Hz tone and go off-line if no DTMF tones have been received for 20 seconds; there is no need to wait for this tone before hanging up.

CW messages are sent with a 900Hz tone; multiple responses are sent in the order they appear in the list.